TITLE: Wellbore Seal Device

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FIELD OF THE INVENTION

The invention relates to friction seals used in wellbores, whether metal-to-metal or other-material-to-metal, used to provide a fluid-tight boundary between a zone uphole of the seal and a zone downhole of the seal, and which are usually run into the wellbore in a run-in position and set once they are positioned in the wellbore.

BACKGROUND OF THE INVENTION

Friction seals are used in wellbores, such as oil and gas wells. These seals are used in situations in which the annulus between two essentially coaxial tubular members, such as a casing and a drill string, must be split into an uphole zone and a downhole zone which are in fluid isolation from each other.

Such seals, like that disclosed in United States Patent No. 5,333,692 to Baugh, *et al.*, may comprise a circular sealing ring which is mechanically mounted to the outer circumference of the inner tubular member. In the run-in position, this sealing ring and its mount are held in relatively close proximity to the inner tubular member, so that the inner tubular member and the seal may freely transit downhole into the proper setting position. Once in the setting position, the sealing ring must be forced outward into secure contact with the inner surface of the outer tubular member.

This sealing action is usually accomplished by actuating a setting device, such as a wedge-shaped ring, and using the setting device to force the sealing ring outward, deforming

its mechanical mounting to the inner tubular member as necessary. Once sufficient force is applied, the sealing ring is forced into a tight surface-to-surface sealing arrangement between the outer surface of the sealing ring and the inner surface of the outer tubular member.

In the annulus between the inner and outer tubular members, the seal thus creates an uphole zone and a downhole zone which are in fluid isolation from each other. Leakage around the inner surface of the sealing ring is generally prevented by the presence of the wedge or other setting device which was used to force the sealing ring outward.

However, these sealing arrangements are not entirely reliable. Excess hydraulic pressure in the annulus between the two tubular members can cause the seal to slip in one direction or the other, pushing the seal out of the desired position. This situation may also cause deformation of the sealing surface with resultant leakage.

Accordingly, it is desirable to provide a sealing apparatus which utilizes any unbalanced or excess up-hole or down-hole hydraulic pressure to enhance the sealing force and to reinforce the strength of the seal.

It is an object of the invention to provide a seal for use in a wellbore which, once set, is reinforced by hydraulic pressure exerted against the sealing device from either an up-hole or a down-hole direction.

SUMMARY OF THE INVENTION

The invention is a settable seal for use in a wellbore which is mountable to a first tubular member, such as a casing string. In its initial position, the seal is maintained

in relatively close relationship to the outer surface of the first tubular member. The first tubular member may be run downhole essentially coaxially with a second tubular member which has an inner diameter sufficient to allow passage of the first tubular member and any devices attached thereto, such as the sealing device.

Once the sealing device attached to the first tubular member has been positioned at a desired setting depth, it is necessary to actuate the setting mechanism and set the seal. This process is normally accomplished by applying force either above or below the sealing device and forcing one part of the sealing mechanism to move relative to another. Those of skill in the art will recognize that the process of controlling the force above or below the sealing mechanism may be accomplished in a number of ways. Further, the act of setting the sealing mechanism may be accomplished by moving the sealing ring itself in one direction or the other relative to the longitudinal axis of the first tubular member, or by moving another part of the sealing mechanism and maintaining the sealing ring essentially stationary relative to the longitudinal axis of the first tubular member.

Moreover, those of skill in the art will also recognize that the "up" or "down" orientation of the sealing device may be inverted without affecting the functioning of the device, and so the choice of orientation is a question of engineering choice. Accordingly, the function of the seal and the manner of setting it is discussed herein as though the seal is essentially stationary relative to the longitudinal axis of the first tubular member, and as though the sealing ring is positioned uphole of its mounting to the first tubular member. However, this description is by way of example only and is not limiting of the invention.

Applying pressure to a setting device, such as a cylindrical wedge mounted around the outer circumference of the first tubular member, forces the wedge into the annulus between the sealing ring and the first tubular member, thus deforming the ring and its mounting outward and forcing the outer surface of the sealing ring into a tight sealing contact with the inner surface of the second tubular member.

The wedge or other actuating device may be initially positioned in a "ready" position and restrained in that position with shear pins, or with another releasable holding device. Those of skill in the art will recognize that the purpose of such a holding device is to prevent premature setting to the seal, and thus that the choice of holding device is a matter of engineering choice appropriate to the circumstances. Further, it is preferable to provide a locking mechanism, such as a ratchet, between the first tubular member and the actuating device to prevent the actuating device from reversing direction once it has been moved into position to actuate the seal.

In accordance with the invention, the actuating device and the inner surface of the sealing ring are designed so that a first cavity exists between the actuating device and the inner surface of the sealing ring. In the preferred embodiment, this first cavity extends into the volume between the outer surface of the first tubular member and the inner surface of the mechanical connection between the first tubular member and the sealing ring. Fluid communication exists between the annular volume either above or below the sealing device and the first cavity.

As discussed above, this description and the detailed description of the drawings below reflect fluid communication between the cavity and the annular volume above the sealing device. However, those of skill in the art will understand that, for example, vertical inversion of the sealing mechanism is possible without constraining its function.

The fluid communication between these two regions may be accomplished in a variety of ways. For example, a wedge-shaped actuating device may have ribs formed on its outer surface, thus creating fluid channels between the outer surface of the wedge and the inner surface of the sealing ring. As an alternative example, channels may be formed in the inner surface of the sealing ring.

This fluid communication may be effected without detriment to the function of the seal, because the mechanical connection between the first tubular member and the second tubular member may be made sufficiently strong to preclude leakage from the first cavity. In the preferred embodiment, this mechanical connection may be held in position relative to the longitudinal axis of the first tubular member by positioning it against a stop ring, and the stop ring may itself be held in place by the provision of a stop ring. Further, a seal, such as an o-ring seal, is provided between the inner surface of the mechanical connection and the outer surface of the first tubular member. Accordingly, the mechanical connection of the sealing ring to the first tubular member may be securely positioned and made fluid-tight, so that the first cavity will not inadvertently create fluid communication between both ends of the seal. Additionally, the mechanical connection is preferably formed of ductile steel of sufficient thickness to provide the strength needed to prevent leakage.

In accordance with the invention, the fluid communication between the first cavity and the annular space either above or below the seal means that increased fluid pressure in the annular space will increase the fluid pressure in the first cavity. Accordingly, the seal is "boosted" by such increased pressure, because additional force is asserted outwardly on the sealing ring, forcing it into tighter contact with the inner surface of the second tubular member.

Similarly, increased fluid pressure in the annulus from the opposite direction will also boost the seal, because that pressure will tend to drive the mechanical connection and the sealing ring further against the actuating mechanism. In the preferred embodiment, the use of a wedge-shaped actuating mechanism will cause such pressure to again force the sealing ring further outward and into tighter contact with the inner surface of the second tubular member.

An alternative embodiment of the invention comprises a first sealing ring and a second sealing ring, each mechanically connected to the first tubular member. In this embodiment, the first and second sealing rings are each selectively positionable into a sealing relationship with the inner surface of the second tubular member by setting devices, such as cylindrical wedges. The first and second sealing rings are mechanically connected to the first tubular member in a vertically opposed configuration.

Between the first sealing ring and its respective setting device is a first cavity which is in fluid communication with the annular volume between the first and second tubular members at one end of the seal. Between the second sealing ring and its respective setting

device is a second cavity which is in fluid communication with the annular volume between the first and second tubular members at the other end of the seal. In the preferred embodiment, the first and second cavities extend into the volume between the first tubular member and the respective mechanical connections to the first and second sealing rings.

When the seal of this embodiment is moved from the run-in position to the set position, force is applied to at least one of the setting devices. In the preferred embodiment, one setting device will be secured relative to the first tubular member, and the mechanical connections of the first and second sealing rings may be shifted relative to the first tubular member in accordance with the application of force to the other setting device. In this manner, one sealing ring is pushed into its set position by its motion relative to the setting device. In this position, the mechanical connection to the sealing rings will no longer be able to move relative to the first tubular member. Thus, the other sealing ring will also be made stationary relative to the first tubular member, and continued application of force to the non-stationary setting device will force this sealing ring into sealing relationship with the inner surface of the second tubular member.

Because the first and second cavities are in fluid communication with the annular volume at their respective ends of the seal, hydraulic pressure applied at either end of the seal will boost the seal by increasing the hydraulic pressure in the cavity at that end of the seal and thus increase the sealing pressure against the sealing ring.

Accordingly, the seal of this invention provides a seal which is boosted by increased hydraulic pressure from either direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a half-sectional view of one embodiment of the invention in the run-in position.

Fig. 2 is a half-sectional view of the embodiment of the invention shown in **Fig. 1** in the set position.

Fig. 3 is a half-sectional view of an alternative embodiment of the invention in the run-in position.

Fig. 4 is a half-sectional view of the embodiment of the invention shown in **Fig. 3** in the set position.

Fig. 5 is a half-sectional view of an alternative embodiment to the embodiment shown in **Fig. 1**, depicted in the set position.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to **Fig. 1**, one embodiment of the seal of the invention is shown in the run-in position. The seal is mounted on a first tubular member **102**, which is run downhole within second tubular member **104**, such as a casing. The seal comprises a sealing ring **106** which is mounted on the first tubular member **102** by a mechanical connection **108**. The outer surface of the sealing ring **106** may be covered with an elastomer material **110** which can enhance the gripping and sealing qualities when the sealing ring **106** is pressed into contact with the inner surface **105** of the second tubular member **104**.

Mechanical connection **108** comprises an o-ring seal **126** to prevent leakage between the mechanical connection **108** and the outer surface **103** of the first tubular member **102**.

Additionally, mechanical connection **108** is held into position relative to the longitudinal axis of the first tubular member **102** by stop ring **120**, which in turn is locked to the first tubular member **102** by lock ring **122**.

When the sealing device is set, sealing ring **106** will be forced outward into sealing contact with the inner surface **105** of the second tubular member **104** by actuating member **112**. The wedge shape of actuating member **112** also comprises ribs **114** which provide a fluid pathway between the actuating member **112** and the sealing ring **106**.

Actuating member **112** will be moved into its set position by actuating setting member **116**, which is initially held into position by shear pins **118**. Seal **119** prevents leakage between the setting member **116** and the first tubular member **102**. Those of skill in the art will recognize that setting member **116** may be actuated by applying force against setting member **116**, shearing shear pins **118** and forcing actuating member **112** into its set position. Ratchet **124** provides locking force to prevent reverse motion of setting member **116** once it is actuated.

Referring now to **Fig. 2**, the seal embodiment of **Fig. 1** is shown in the set position. Setting member **216** has been actuated, shearing shear pins **218**, and leaving tails **217** in the first tubular member **202**. The movement of setting member **216** has forced actuating member **212** to move relative to the longitudinal axis of the first tubular member **202**, and pressing sealing ring **206** outward into sealing contact with the inner surface **205** of the second tubular member **204**. Ratchet **224** prevents actuating member **212** from being forced backward by spring pressure.

The ribs **214** on actuating member **212** create flow paths **231** between the first annular space **232** and first cavity **230**. First cavity **230** includes the interstitial spaces between the ribs **214** (radially between sealing ring **206** and the actuating member **212**) and preferably extends into the volume between outer surface **203** of the first tubular member **202** and the mechanical connection **208**.

The sealing ring **206** and the mechanical connection **208** are deformed by movement of the actuating member **212** so that the sealing ring **206** provides a tightly sealing contact with inner surface **205** of the second tubular member **204**.

Further, second cavity **234** is in fluid communication with the second annular space **236**, but first and second annular spaces **232**, **236** are in fluid isolation from each other. Thus, an increase in hydraulic pressure in first annular space **232** causes an increase in pressure in first cavity **230**, thus exerting a greater outward force on sealing ring **206** and "boosting" the seal. Similarly, an increase in hydraulic pressure in second annular space **236** increases the hydraulic pressure in second cavity **234**. The component of the pressure in second cavity **234** which is parallel to the longitudinal axis of first tubular member **202** will have the effect of forcing the sealing ring **206** tighter against actuating member **212**, and thus into a tighter sealing contact with the inner wall **205** of the second tubular member **204** due to the wedge shape of actuating member **212**, again boosting the seal.

Those of skill in the art will recognize that "up" and "down" may be reversed in **Figs. 1** and **2** without affecting the function of the seal. Accordingly, first annular space **232** can either be uphole or downhole from the sealing device.

Referring to **Fig. 3**, an alternative embodiment of the device in the run-in position is shown. The seal is mounted on a first tubular member **302**, which is run downhole within second tubular member **304**, such as a casing. The seal comprises first sealing ring **306** which is mounted on the first tubular member **302** by mechanical connection **308**, and second sealing ring **307** which is also mounted on the first tubular member **302** by mechanical connection **308**. The outer surfaces of first and second sealing rings **306, 307** may be covered with an elastomer material **310** which can enhance the gripping and sealing qualities when first and second sealing rings **306, 307** are pressed into contact with the inner surface **305** of the second tubular member **304**.

Mechanical connection **308** comprises an o-ring seal **326** to prevent leakage between the mechanical connection **308** and the outer surface **303** of the first tubular member **302**. Seal **319** prevents leakage between actuating member **316** and the first tubular member **302**. Those of skill in the art will recognize that actuating member **316** may be actuated by applying force against actuating member **316**, shearing shear pins **318** and forcing first wedge **312** into its set position. Ratchet **324** provides locking force to prevent reverse motion of actuating member **316** once it is actuated.

When the sealing device is to be set, force will be applied to actuating member **316** sufficient to shear pins **318** and drive first wedge **312** against sealing ring **306**. Friction between wedge **312** and sealing ring **306** initially forces first and second sealing rings **306, 307** and mechanical connection **308** to shift relative to first tubular member **302**, causing second sealing ring **307** to push against second wedge **313**. Second wedge **313** is precluded

from moving relative to first tubular member **302** by positioning ring **340**. Second sealing ring **307** is thus deformed and forced outward into a sealing relationship with inner surface **305** of second tubular member **304**. When the sealing force between second sealing ring **307** and inner surface **305** is sufficient to preclude further movement of second sealing ring **307**, the continued motion of first wedge **312** relative to first tubular member **302** forces first sealing ring **306** into a sealing relationship with inner surface **305**.

First wedge **312** also comprises ribs **314** which provide a fluid pathway between first wedge **312** and first sealing ring **306**. Similarly, second wedge **313** comprises ribs **315** which provide a fluid pathway between second wedge **313** and second sealing ring **307**.

Referring now to **Fig. 4**, the seal embodiment of **Fig. 3** is shown in the set position. Actuating member **416** has been actuated, shearing shear pins **418**, and leaving tails **417** in the first tubular member **402**. The movement of actuating member **416** has forced first wedge **412** to move relative to the longitudinal axis of the first tubular member **402**, and has moved first sealing ring **406**, mechanical connection **408**, and second sealing ring **407** relative to first tubular member **402**. Second sealing ring **407** has been forced by second wedge **413** into sealing contact with the inner surface **405** of the second tubular member **404**. Similarly, first sealing ring **406** has been forced by first wedge **412** into sealing contact with the inner surface **405**. Ratchet **424** prevents first wedge **412** from being forced backward by spring pressure.

Ribs **414** on first wedge **412** create flow paths **431** between the first annular space **432** and first cavity **430**. First cavity **430** includes the interstitial spaces between the ribs **414**

(radially between first sealing ring **406** and the first wedge **412**) and preferably extends into the volume between outer surface **403** of the first tubular member **402** and the mechanical connection **408**. Similarly ribs **415** on second wedge **413** create flow paths **433** between the second annular space **436** and second cavity **438**. Second cavity **438** includes the interstitial spaces between the ribs **415** (radially between second sealing ring **407** and the second wedge **413**) and preferably extends into the volume between outer surface **403** of the first tubular member **402** and the mechanical connection **408**.

The first and second sealing rings **406, 407** and the mechanical connection **408** are deformed by the setting operation so that first and second sealing rings **206, 207** provide a tightly sealing contact with inner surface **405** of the second tubular member **404**.

Further, first cavity **430** is in fluid communication with first annular space **432**, and second cavity **438** is in fluid communication with the second annular space **436**, but first and second annular spaces **432**, **436** are in fluid isolation from each other. Thus, an increase in hydraulic pressure in first annular space **432** causes an increase in pressure in first cavity **430**, exerting a greater outward force on first sealing ring **406** and "boosting" the seal. Similarly, an increase in hydraulic pressure in second annular space **436** increases the hydraulic pressure in second cavity **438**, exerting a greater outward force on second sealing ring **407** and "boosting" the seal..

Those of skill in the art will recognize that "up" and "down" may be reversed in **Figs. 3** and **4** without affecting the function of the seal. Accordingly, first annular space **432** can either be uphole or downhole from the sealing device.

In another alternative embodiment, referring to **Fig. 5**, fluid communication between the first cavity **508** and the first annulus **501** is maintained by providing a first fluid pathway between wedge **510** and sealing ring **512**, wherein fluid may pass inlet **502**. A fluid port **504** in wedge **510** provides fluid communication to a second fluid pathway **506** and then to first cavity **508**. Those of skill in the art will recognize that such modifications to the fluid pathway do not alter the function of the invention.

Other variations in the construction of the invention may be made without departing from the spirit of the invention, and those of skill in the art will recognize that these descriptions are provide by way of example only, without limiting the scope of the invention.